International Journal of Engineering and Applied Sciences (IJEAS)
ISSN: 2394-3661, Volume-3, Issue-8, August 2016

Improving Energy Generation in Nigeria by Using Combustible Waste as Alternative Fuel

Osafehinti Samuel Ibikunle

***Abstract*— This paper presents the strategy of improving energy generation in Nigeria by using combustible waste as alternative fuel in power plant. Household and commercial waste is being considered as fuel for electrical power generation .data obtained include volume of waste produce in sampled building of urban, sub-urban and rural communities from field source through direct collection of total waste produce per building in each community considered .sample of waste was measured and classified by percentage to determine the percentage combustible wood related waste usable as fuel in the power plant .estimated combustible waste in Edo state is 360,224 Kg per day while in Ondo state 376,228.3 Kg per day this can independently run a 1 Mw-h waste power plant on daily basis. The process flow diagram and the energy conversion strategy to be deployed is discuss**

***Index Terms*— Household, commercial, waste, combustible, fuel, generation, power plant.**

I. Introduction

Energy is the ability to do work it is important in all sector of the economy. The standard of living in a given country can be directly related to the per energy consumption (Nag 2007) energy appear in many forms but exhibit the ability to produce vital effect in common .it exist in multiple forms, mechanical, thermal, chemical, sound, electrical, to mention a few. One form of energy can be converted into another by the use of suitable technology. Bulk electrical power is produce by special plant known as generating station. The generation stations in Nigeria are predominantly gas thermal station utilising natural gas as fuel

The Alternative fuel considered in this paper is combustible waste generated at domestic and commercial premises. The energy conversion strategy is also presented using Edo and Ondo state as a case study

II. METHODOLOGY

A. Alternative Fuel

The Alternative fuel considered for this studies are wood related combustible waste generated at home.

B. Data Collection of House hold waste

According to Babayemi et al (2009) volume of waste generated per person per day in different Nigerian cities are as follows; Abeokuta 0.66Kg , Ado Ekiti, 0.71Kg, Akure 0.54Kg, Ile-Ife 0.46Kg, Ibadan 0.7Kg, Benin City 0.54Kg, Abuja 0.58Kg and the Lagos State management authority estimated the volume of waste generated per person per day to be 0.5kg in Lagos. To further using this fact, a sample was taken in Ondo and Edo States in urban, sub-urban and rural areas. 100 building were selected in the urban and sub-urban and 40 building in the rural areas to estimate the volume of waste generated per person in both States. Akure was classified as urban, Ifon sub-urban and Eporo as rural settlement in Ondo State while in Edo State, Benin city is classified as urban, Sabogida Ora sub-urban and Agbanikaka as rural community.

As data were obtained from field source through direct collection of total waste generated per building in each of the various communities considered. The numbers of occupants in the building are identified to determine the overall waste generated per person. building sample were taken from Ugbowo, Aduwawa, New Benin and GRA in Benin City, while in Akure, Ijoka, Aule Okejebu and Alagbaka area were considered. Sample of waste was measured and classified by percentage composition, food, plastic, paper, metal, glass, classified combustible and unclassified combustible (Dennis, 2012) to determine the percentage combustion and usable as fuel for this power plant. Figures 1-3 and 4-6 show data sample of waste generated per building in Ondo and Edo state respectively.

Combustible waste consider as fuel in this category is sum of composition of paper, leaf and unclassified combustible.

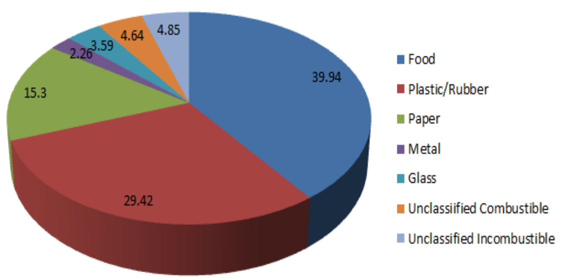

Figure 3.1: Classification of waste by percentage in Akure Ondo State (Urban)

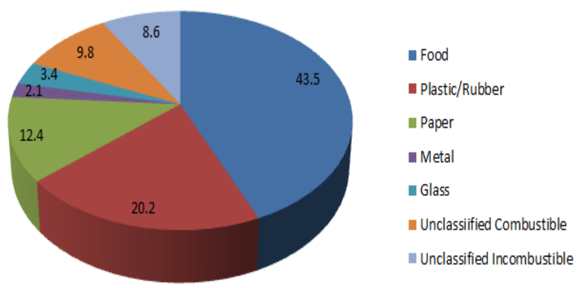

Figure 3.2: Classification of waste by percentage in Ifon Ondo State (Sub-Urban)

Osafehinti Samuel Ibikunle, Electrical Engineering Department, Rufus Giwa Polytechnic, PMB 1019, Owo, Ondo State Nigeria, +2348030677474

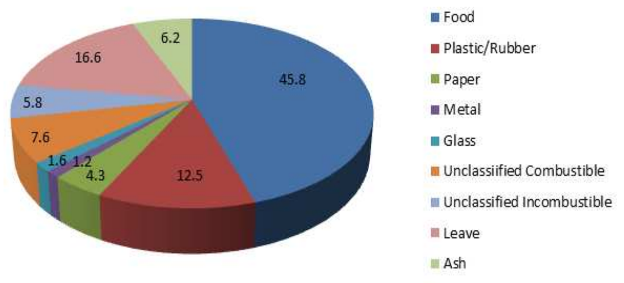

Figure 3.3: Classification of waste by percentage in Eporo Ondo State (Rural)

III. EVALUATION OF COMBUSTIBLE WASTE GENERATED IN ONDO STATE

Table 1 show population distribution in percentage by urban, sub urban and rural settlement.

Table1: Population distribution in % by urban, sub urban and rural settlement (source federal ministry of statistics)

Description of settlement	Percentage distribution (PD)
Urban	39.08
Sub-urban	15.52
Rural	45.40

Population of Ondo State is 3,460,877 (Federal ministry of statistics)
UP in Ondo State = PD x TP
39.08 x 346, 087, 7 = 1,352,511
SUP = 15.53 X 3,460,877 = 53,747,419.81
RP = 45.40 x 3,460,877 = 1,571,238
UW = UP x AWG/P = 1,352,511 X 0.464
= 628,511.8617kg
CWCF in urban = 628,511.861 X 0.1994
= 125,325.27kg
SUW = SUP x AWG/P = 537,128 X 0.64
= 344,299.048kg
CW in sub urban = SUW x %CWCF
= 344,299.048 x 0.222 = 76,434.388Kg
RW = RP x AWG/P = 1,571,238 X 0.38
= 597,070.44kg
CWCF in rural setting =RW x % CWCF
= 597,070.44 X 0.285 = 170,165.07kg
TCWG in Ondo State = 125,325.27 + 76,434.388 + 170,165.07 = 371,864.72Kg per day.

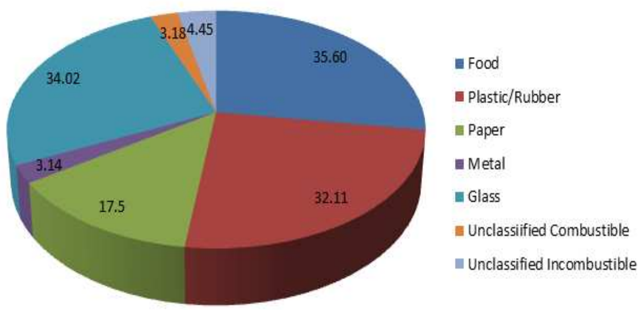

Figure 3.4: Classification of waste by percentage in Benin Edo State (Urban)

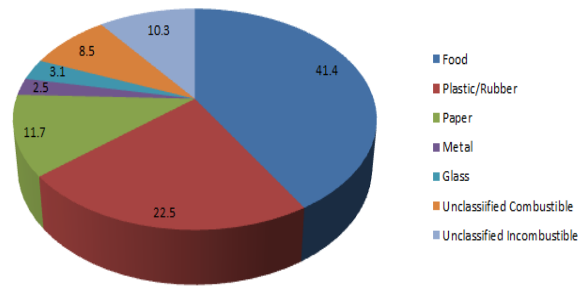

Figure 3.5: Classification of waste by percentage in Sabongida-Ora Edo State (Sub-Urban)

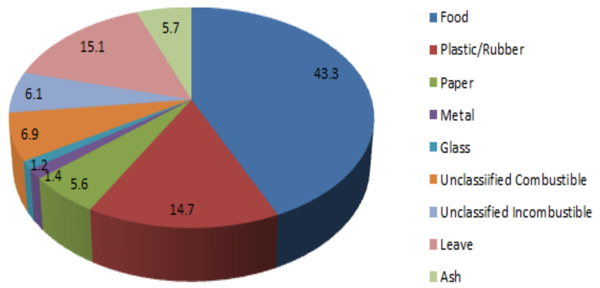

Figure 3.6: Classification of waste by percentage in Agbanikaka Edo State (Rural)

Evaluation of Combustible Waste Generated in Edo state
Population (TP) in Edo State = 3,233,366
(Federal ministry of statistics)
UP= TP x PD (Table3.7) = 39.08 x 3,233, 366 = 1,263,600
SUP = TP x PD =15.53 x 3,233,366 = 501,818
RP =TP xPD = 45.40 x 3,233,366 = 1,467,948
UW = UP x AWG/P= 1,263,600 x 0.4984
= 629,778.24kg
CWCF in urban =UW x% CWCF = 629,778.24 x 0.21 =132,253.43kg
SUW = SUP x AWG/P = 510,571 x 0.656
= 335,096.608kg
CWCF in sub urban =SUW x %CWCF
= 335,096.608 x0.202= 67,285.51kg
RW = RP x AWG/P = 1,467,948 X 0.404
= 593,050.93
CWCF in rural =RW x % CWCF = 593,050.93 x 0.276 = 163,682.1kg
Total combustible waste generated in Edo State
= 132,253.43 + 67,285.51 + 163,682.1
= 363,221.04 kg/day

A. Fuel and Combustion

Fuel refers to a substance that burns in air to produce carbon IV Oxide, water vapour and light with evolution of heat.

To be classed as a fuel, a material must contain elements which will combine rapidly with oxygen to initiate combustion. Substances are classed as fuels based on different yardsticks; they may be classed according to whether they are in a solid, liquid or gaseous state. In this paper attention would be focused on wood related waste with under-listed percentage chemical composition bymass:49% C 6% H_2O; 44% O_2; 0.4% N_2 and 0.6% Ash

Wood burns more clearly than oil or coal and causes much less pollution. A few wood burning power plants are operating in USA (Nag, 2009; pg. 167). Combustion is the high temperature oxidation of the combustible elements (C, H_2, S etc.) fuel with heat release proper control of the right

ISSN: 2394-3661, Volume-3, Issue-8, August 2016

amount of excess air enhances optimum combustion efficiency. The amount of excess air supplied varies with the type of fuel and the firing conditions; It may approach a value of 100% but modern practice tends to use 20 % to 50 % excess air (Rajput, 2011;). Let the excess air be 20 %

B. Design criteria

- Assuming the air supplied is 20 % in excess
- Air contains 21% O_2 and 79% N_2 (other inert gases, e.g. Argon inclusive) by volume and in terms of mass, it contains 23% O_2 and 77% N_2 (Nag 2011, pg.176 and Rajput 1997, pg. 187))

Table 2: Computation of mass of Flue Gas per kg of fuel at 20 % excess air

FUEL (kg)	O_2 Required	Dry Product
C = 0.40	$C + O_2 = CO_2$ (1.306666667)	0.49 x $\frac{44}{2}$ = 1.796666667 (CO_2)
H_2 = 0.06	$H_2 + O = H_2O$ (0.48)	0.06 x $\frac{18}{2}$ = 0.54 (H_2O)
N2 = 0.004		- 04 (N_2)
O2 = 0.44		
Ash = 0.006		
Total	1.786666667	

Mass of O_2 to be supplied = Mass of O_2 supplied – Mass of O_2 already present

1.786666667 – 0.44 = 1.34666667 kg/kg fuel

Stoichiometric air required, which is equal to the minimum mass (volume) of air required.

Minimum mass of Air supplied = 1.34666667 x $\frac{100}{23}$ = 5.855072764 kg

At 20 % O_2, excess air supplied = 5.855072764 x 1.2 = 7.026086957 kg

N_2 present in the air = 7.026086957 x $\frac{77}{100}$

= 5.416086907 kg

Total mass of N_2 present in the flue gas

= 5.416086907 + 0.004 = 5.414086257 kg/kg waste wood

Mass of free O_2 due to excess air =5.855072764 x 0.2 x $\frac{23}{100}$ = 0.26933333kg/kg waste wood

Mass of dry flue gas = MCO_2 + MN_2 + MO_2

= 1.70666667 + 5.414086257 + 0,269933334

= 7.480086258 kg/kg waste wood

Table 3 Volumetric Analysis of fuel at 20 % Excess Air

In terms of % Weight	Mass (kg)	In terms of Mole Volume	O_2 Requirement
C = 49	12	$\frac{49}{12}$ = 4.0833333	$C + O_2 – CO_2$ (4.0833333)
H_2 =6	2	$\frac{6}{2}$ = 3	$H_2 + {}^{1}/_{2}\ O_2 – H_2O$ (1.5)
N_2 = 0.4	28	$\frac{0.4}{28}$ = 0.014285714	
O_2 = 44	32	$\frac{44}{32}$ = 1.375	
Ash = 0.6		$\sum O_2$ = 4.20833333Mol/vol/WW	

Step III: Air Requirement

Minimum volume of air required for combustion = 4.20833333 x $\frac{100}{21}$

= 20.03968254 Nm^3

At 20% excess air, volume of air required = 20.03968254 x 1.2

= 24.047619048 Nm^3

Volume of N_2 present in the Air = 4.20833333 x $\frac{79}{100}$

= 3.3245833 Nm^3

Total volume of N_2 = 3.32455833 + 0.014285714

= 3.3388690473 Nm^3

Volume of free O2 due to excess air = 20.03968254 x 0.2 x $\frac{21}{100}$

= 0.8416666668 Nm^3

Hence, the combustion air required for 1 kg Waste Wood (fuel) is 20. 03968254 Nm^3 and in excess air is 24.047619048 Nm^3

Table4: Volume of Flue Gas in100kg of Combusted Wood

Reactant	**Combustion reaction**	**Product (Mole Vol)**
C	$C + O_2 – CO_2$	4.08333333
H_2	$H_2 + {}^{1}/_{2}\ O_2 – H_2O$	3.0
O_2		0.8416666668
N_2		3.3388690473
$\sum Volume$		11.2638690441

100 kg (Basis) of waste wood burned to produce 11.2638690441 x 22.4 Nm^3 flue gases

1 kg of waste wood produced 11.2638690441 $\frac{22.4}{100}$

= 2.523106658784 Nm^3

Table 5. Specific Weight of Flue Gas

Flue Gas	Composition (Mol/Vol)	Molar Mass	Weight
CO_2	4.08333333	44	179.6666666652
H_2O	3.0	18	54
N_2	3.3388690473	28	93.488333324
O_2	0.8416666668	32	26.9333333379
			354.0883333272

Therefore, the specific weight of flue gas = $\frac{3.540883333272}{2.523}$ = 1.403382343 kg/Nm^3

Calorific value: this refers to the heat energy released by the complete burning of unit quantity of fuel; it is also called specific energy or heat rate. The heat rate of solid substances is determined with Calorimeter.

Enumerated below is the method used in computing the Calorific value of wood

Table 6. Calorific Value of Wood

Reactant	Reaction	Heat of combustion (kcal/kg)	Heat evolved (kca l)
C	$C + O_2 – CO_2$	(+)8137.5	8137.5 ($\frac{49}{100}$) = 3, 787.375
H_2	$H_2 + \frac{1}{2}O_2 – H_2O$	(+)28905	28905($\frac{0.5}{100}$) = 144.5
$\sum H_{comb}$			4, 131.9

The values of Heat of combustion were obtained from heat of combustion Table
According to Dulong, the heat of evaporation of (2 x 0.84416666668) 1.68333333 mol/vol of water should be subtracted from this Calculated Value (CV).
Hence, the calorific value of waste wood is 3, 841.89 kcal/kg (16, 085.74221kJ/kg). The calorific value calculated based on the constituents of the fuel used is called

C. **Fuel Analysis for one MW-h power plant**

Calorific value of wood related fuel =16086 (Nag 2008)
Mass of fuel per hour =3.479997888 (Nag 2008)
Mass of fuel required per day =83.51994 t/hr
Mass of fuel required per year =30,484.78 t/hr

Estimated MW-h of Energy Generation from Domestic Waste
(i) In Ondo State
Available combustible waste (Paper, leave and classified combustible) = 376, 340.3kg/day
376, 340.3 x 365 = 137, 364.2097 ton/yr
Generating Plant fuel usage = 118, 742.6899ton/yr
MW-h of energy that can be generated using domestic waste = $\frac{137364.2097}{118,742.6879}$

1.1568 -h (≈ 1.0 MW-h)

In Ondo State, a 1.0 MW-h Power Plant could be run for 1 year using combustible waste

(i) **In Edo State**

Available combustible waste = 360.223 kg/day (360.223 ton/day)
= 360.223 x 365 = 131481.395 ton yr
MW-h of energy that can be generated
$= \frac{131481.39}{118,742.6879}$

1.10727991 (≈1.0 MW-h)

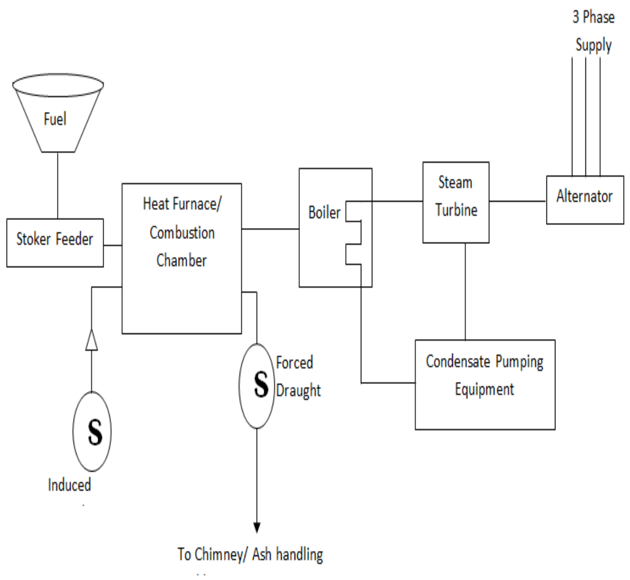

Figure 7 Schematic Diagram, Model for Power Generation Employing Wood and Wood Residue

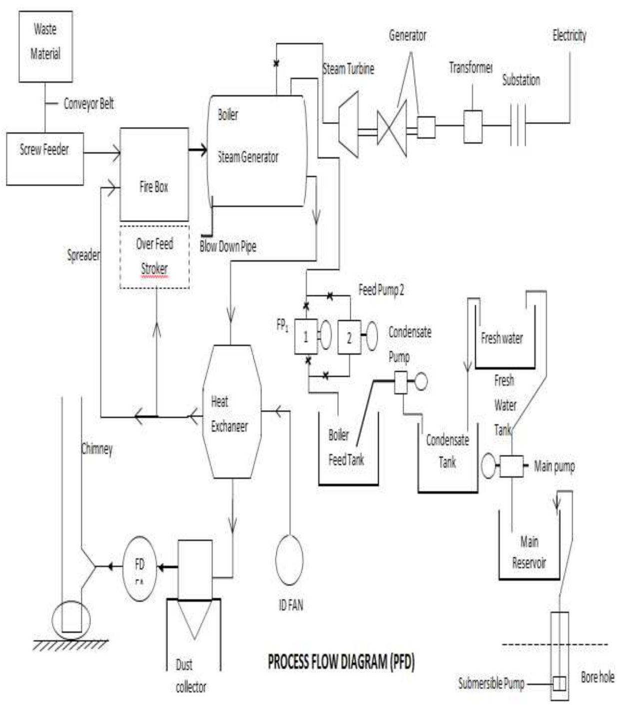

FIGURE 8, PROCESS FLOW OF ONE MEGAWATT HOUR WASTEFUEL POWER PLANT

The waste to power generation system will convert commercial, municipal, industrial waste, wood and palm kernel residue to heat with added benefit of generating electricity. The process flow diagram (PFD) is shown in fig 8

A. Waste Preparation:

Municipal and industrial waste contains varying degrees of water. It is necessary to remove this water from waste prior to injecting it into waste segregating unit. The useable portion is first dried in ambient condition and later through rotary dryer to remove bond water within the waste matrix.

This set of waste is feed into the shredding machine. Reducing them to smaller size which passes through the screw feed system into the fire box.

B. Screw feeder/spreader:

It consists of a helicoids screw fitted to a shell. The driving mechanism is connected to one end of the shell and the other end is suspended in an enclosed ball bearing. The screw while rotating in a trough housing transfer fuel from the input and to the outlet which is connected to an opening to the over feed shocker in the firebox. Below the opening is an air inlet, a branch from the ID fan help to spread the fuel on the stroker. This function as the fuel spreader.

C. Waste conversion:

the waste conversion is utilizing the stored heat value in the waste. The combustion of fuel in air to produce heat is exhibited in this stage.

The process is characterized with flame impregnated in the furnace. This unit consist of overfeed stroker firebox induced and force draught system.

D. Overfeed stroker:

It consists of induced draft system, forced draft, wind Box air duct, air nozzles, Fan, driving motor and blower. Fuel is delivered to the grate from the feeder and spreader powered by a motor driven variable speed driver. The grate which is an assembly of perforated cast iron section called Tuyere is positioned on top of the wind box. The combustion air is supplied to the grate through the wind box and the tuyeres from the ID fan. Sea sand are placed on the tuyere as combustion bed to serve as refractory material to sustain the temperature of the fuel and separate tuyere from heat of combustion. American standard book for boiler and Elloth 1980 explain that when using stroker boiler, output is reduced by 42% and large amount of air are required for combustion. This is compensated for with the size and rating of fan to overcome this feature two air system are deployed ID fan and FD fan.

E. The forced air system

Two forced air system are deployed. The under fire forced draft and over fire and swirling draft i.e induced draft. The system is designed to supply excess air to allow for variability in fuel condition, moisture content, particle sizes and species of wood and fuel type. This is obtained by taking air (fresh or preheated) of the chimney. In this system the fuel gas is less dense than the ambient air surrounding the boiler, the denser column of ambient air forces combusted air into and through the furnace and boiler with the aid of high speed fan.

F. Heat Furnace/Combustion chamber

The furnace (fire box) is a chamber in which chemical energy in fuel is combusted to liberate heat energy. It also provides support and enclosure for the combusting equipment and heat exchanging water tube. The furnace wall will be made of high temperature fire bricks and refractory material, heat resistance fire concrete, bond chemical fibre cement (sugar sulphuration and calcium silicate). This material has resistance to change its shape, weight and physical properties at high temperature.

G. Steam Generation

The steam generators utilize the heat produce from the waste in the fire box to heat up water in the water tube type unit to produce steam. The tubes are made from block steel of 10mm thickness and 5m long. The tubes are connected to water header and steam header. The water headers the steam headers are positioned at the same level and steam level in the boiler. The boiler is a close vessel in which water under pressure is transformed into steam by application of heat. The boiler to be use in this power plant is the water tube boiler. The water is inside the tube and hot gases in combustion chamber are outside the tube. The fluid gas in fire box is blown through the boiler via the force draught fan to the chimney.

IV. FINDING

The total combustible waste produce in Ondo state is 376,340.3 Kg per day, this can generate 1.156Mw-h while in Edo state 360,228 Kg of waste is produce per day, this can also generate 1.107 Mw-h. This approach can be used to complement power generation in Nigeria

V. CONCLUSION

The waste to power generator provide an additional energy generation platform. This control combustion of waste can be considered as an effective tool for waste disposal, it also helps reduce the health treats associated to waste dump site.

ABBREVIATIONS**:** UP: Urban Population PD: Percentage Distribution, TP: Total Population, SUP: Sub-urban Population, RP: Rural Population, UW: Urban Waste, AWG/P: Average waste generated per person, CW: Combustible waste, CWCF: Combustible waste considered as fuel, SUW: Sub-urban waste, RW: Rural Waste, TCWG: Total combustible waste generated

REFERENCE

[1] Babayemi J.O.,Dauda .K.T, (2009) Evaluation of Solid Waste Generation Categories and Disposal option in developing country A Case study of Nigeria Journal of Applied Science and Environmental Management Vol 13 No 3

[2] Badmus (1999): "Maintenance of Thermal Power Boiler", Lagos: Unpublished Lecture Note for Pupilage, Engineers Egbin thermal station.

[3] Dennis.I.Igbinomwanhia (2012) Characteristic of Commercial Solid Waste in Benin metropolis Nigeria Journal of Emerging Trends in Engineering and Applied Science Vol 3(5) pp 834-838

[4] B.L. Theraja & A.K. Theraja. "A textbook of Electrical Technology. First multicore edition 2005 S Chand & Company Ltd New Delhi.

[5] Donald G. Fink and H. Wayne Beaty: Standard Handbook for Electrical Engineers Fourteenth Edition 2000. McGraw-Hill Toronto

[6] R.K. Rajput: A textbook of power plant engineering. Fourth Edition 2008 Laxmi Publication Ltd New Delhi.

[7] G.D. RAI – An introduction to power plant technology. Third edition 2007 Khanna publisher Delhi.

[8] G.D. RAI: non-conventional energy sources. Fourth edition 2008 Khanna Publisher Delhi.

[9] P.K. Nag Power Plant Engineering third edition 2008. Tata McGraw-Hill New Delhi.

[10] J.B. Gupta: A cause in power systems third edition 2004. Sanjeet Kumar Katari